Validating Numerical Predictions of Floating Offshore Wind Turbine Structural Frequencies in Bladed using Measured Data from Fukushima Hamakaze

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1. Fukushima FORWARD

The government of Japan has started the experimental research project of **the world's first floating offshore wind farm**, which is conducted by the consortium made up of industry-academic-government organization. This project is sponsored by Ministry of Economy, Trade and Industry and named as "Fukushima FORWARD (Fukushima Floating Offshore Wind Farm Demonstration Project)".

The wind farm consists of **three floating offshore wind turbines (FOWTs)** and **a substation** floater. The wind farm's total amount of rating capacity is 14 MW.

http://www.fukushima-forward.jp/

Fig. 1. Overview of Fukushima FORWARD

2. Fukushima Hamakaze (5MW FOWT)

Item	Value
Length	58.9 m
Breadth	51.0 m
Hub height	86.4 m
Draft	33.0 m

Fig. 2. Isometric view and principal particulars

Fukushima Hamakaze is floating offshore wind turbine with a 5 MW horizontal axis wind turbine, has been installed at about 20 km off the coast of Fukushima Prefecture of Japan since July 2016 and is now operating.

The structure of the floating offshore wind turbine is **"Advanced Spar Type"**. Advanced spar is the newly developed structure for FOWT and enables to suppress the motion of the float.

This floater was designed using commercial wind turbine modelling software "Bladed". The purpose of this paper is to **validate the structural frequencies using measured data**.

3. Method of Validation

To validate the first tower natural frequency estimation model, we investigated **several approaches to the modelling** of the floater.

Tab. 1. Investigated models

Model	Structural Flexibility	Dynamic Mooring Lines
#1 Baseline	×	×
#2 Flex	✔	×
#3 Flex + DynML	✔	✔

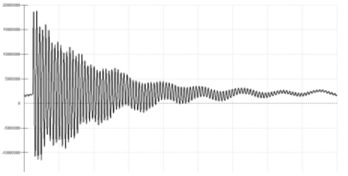

Fig. 3. Hammer test example result

The natural frequencies are extracted through counting the tower base overturning moment peaks after an external impulsive load is applied to the tower top. (like "Hammer test")

4. Modelling Structural Flexibility

The submerged structure was divided into **rigid and flexible sections** and the added mass was distributed to each part. To break down **the added mass into several parts**, the boundary element method hydrodynamics was post processed using outputs of the individual panel potentials.

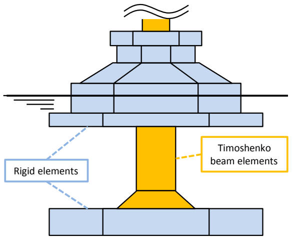

Fig. 4. Flexible structure model

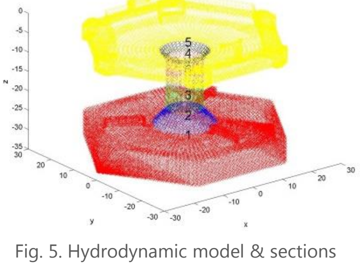

Fig. 5. Hydrodynamic model & sections

5. Modelling Dynamic Mooring Lines

To consider the inertia of the chain and hydrodynamic added mass, dynamic mooring lines were included in the model.

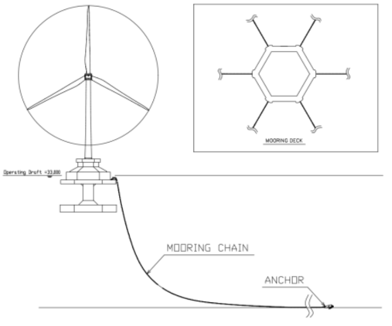

Fig. 6. Mooring arrangement

The FOWT is moored by **six chain catenary**. Nominal diameter of the chain is 132mm. The water depth at which the anchor is installed is 110 to 120 m. The upper end of the chain is connected to the submerged deck.

The lines hydrodynamic loadings are modelled as Morison model.

6. Result and Recommendation

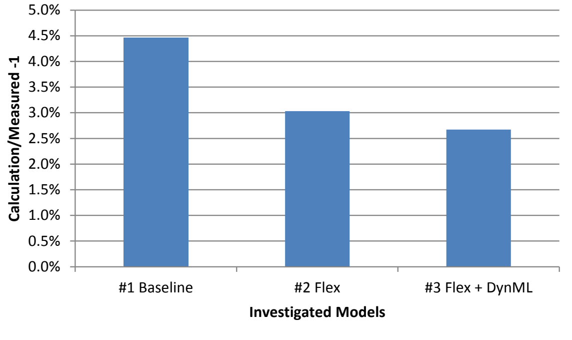

Fig. 7 Comparison result of tower natural frequencies

Each model in Tab.1 has been simulated in Bladed and the results are shown in Fig.7, the percentage difference between the calculation and measured values.

Effect of Structural Flexibility (#1 - #2)

About **1.5% improvement** in the tower frequency prediction can be seen.

Effect of Dynamic Mooring Lines (#2 - #3)

Reducing the tower natural frequency, however the differences are **very small** (0.4%).

- It is recommended to identify where significant flexibilities exist within the floater and model it appropriately for the estimation of the tower natural frequencies. (This will be platform dependent.)
- For this model, dynamic mooring lines could be safely ignored.